FLOW AUDIT STUDY PROTOCOL

THE SAN JOSÉ/SANTA CLARA WATER POLLUTION CONTROL PLANT

Cities and Agencies Tributary to the San José/Santa Clara Water Pollution Control Plant:

San José, Santa Clara, Milpitas, Cupertino Sanitary District, West Valley Sanitation District (including Campbell, Los Gatos, Monte Sereno, Saratoga), County Sanitation Districts 2-3, Sunol and Burbank Sanitary Districts

Program managed by the City of San José, Environmental Services Department
Environmental Enforcement Division

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PREFACE

The Flow Audit Study program, and specifically this document, have been developed after extensive study and review of flow reduction and pollution prevention efforts at commercial, industrial, and institutional facilities in Santa Clara County. This document will provide guidance and establish the industry parameters when preparing and completing the Flow Audit Study (FAS).

This document includes several forms that will assist Dischargers in gathering data, evaluating flow reduction options, and reporting the results. Many of these forms were taken from manuals prepared by the US Environmental Protection Agency (EPA), the San José/Santa Clara Water Pollution Control Plant (Plant) Mass Audit Study (MAS) Protocol of January 1997, and the California Department of Toxic Substances Control.

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ABBREVIATIONS

ADWEF	Average Dry Weather Effluent Flow
AF/yr.	Acre foot per year
AWNS	Acid Waste Neutralization System
City	City of San José
Discharger	Industrial, Commercial, and Institutional Waste Discharger
EDI	Electrodeionization
EE	Environmental Enforcement
EPA	Environmental Protection Agency
ESD	Environmental Services Department
FAS	Flow Audit Study
gpd	gallons per day
IU	Industrial User
IX	Ion Exchange
MAS	Mass Audit Study
MECL	Mass Equivalent Concentration Limit
CEFRM	Cost Effective Flow Reduction Measure
mgd	million gallons per day
NPDES	National Pollutant Discharge Elimination System
PCB	Printed Circuit Board
Plant	San José/Santa Clara Water Pollution Control Plant
POTW	Publicly Owned Treatment Works
RCM	Reasonable Control Measure
RCMP	Reasonable Control Measures Plan
Regional Board	The San Francisco Bay Regional Water Quality Control Board
RO	Reverse Osmosis
SBWR	South Bay Water Recycling Project
SMR	Self-monitoring Report
South Bay	The San Francisco Bay South of Dumbarton Bridge
WMP	Waste Minimization Plan
WTS	Waste Treatment System

BACKGROUND

In response to the California State Water Resource Control Board Order WQ 90-5, the San Jose Action Plan was proposed in 1991 by the City of San Jose on behalf of the San Jose/Santa Clara Water Pollution Control Plant (Plant) and the tributary agencies (Santa Clara, Milpitas, Cupertino Sanitary District, West Valley Sanitation District, County Sanitation Districts 2-3, Sunol and Burbank Sanitary Districts). The overall goal is to protect and restore salt marsh habitat for two endangered species by reducing the amount of freshwater flows from the Plant to below 120 million gallons per day (mgd) average dry weather effluent flow (ADWEF).

The Plant submitted a revised South Bay Action Plan to The San Francisco Bay Regional Water Quality Control Board (Regional Board) in June 1997 and a Contingency Plan in December 1997. The Action Plan and its Contingency Plan were approved and incorporated as permit requirements in the Plant's National Pollutant Discharge Elimination System (NPDES) permit issued by the Regional Board in June 1998. The Contingency Plan is a tiered approach to ensure that the ADWEF is brought and remains below 120 (mgd).

Tier I of the Contingency Plan must be implemented if the measures contained in the 1997 Revised Action Plan do not achieve expected reductions and the ADWEF exceeds 120 mgd during the 1998 regulatory period (the average of the three lowest consecutive month's flows between May and October) or any subsequent year. If Tier I is necessary in 1998, implementation must begin by November 1, 1998. The Tier I measures are as follows:

- Public Awareness Campaign to increase the awareness and acceptance of ultra low flush toilets (ULFTs) and the need for water conservation to reduce flow from all sources to the Plant.

- Mandatory retrofit of bathrooms/lavatories with water saving fixtures (e.g. ULFTs, faucet aerators, and showerheads) and/or secure certification of existing water-saving fixtures upon resale of all residential, commercial, industrial and institutional property.

- Mandatory use of recycled water for landscaping for all customers within the recycled water service area with an annual nonpotable water use of 5 Acre-feet per year (AF/yr.).

- Require all Commercial/Industrial/Institutional dischargers whose flow to the sanitary sewer is 100,000 gallons per day or more to perform a flow audit and implement all cost effective flow reduction measures.

The following Flow Audit Study (FAS) protocol supports the Tier I requirement for Commercial, Industrial, and Institutional flow audits.

INTRODUCTION

1. What is a Flow Audit Study Protocol?

The FAS Protocol is intended to provide guidance for Tier I Dischargers when preparing a FAS. It describes the format required for completing an investigation of a facility's current water usage and of potential water conservation and/or recycling measures.

2. Who Should Complete a FAS?

Any Discharger who discharges an average of more than 100,000 gallons total per day to the sanitary sewer. The baseline time period for calculating average daily flow for Tier I Dischargers is January 1, 1997 – December 31, 1997.

3. Can my company be exempt from the Flow Audit Study Requirement?

Yes, if you meet the following conditions:

A. Your company is using South Bay Water Recycling (SBWR) water in an industrial process by October 31, 1998 and the remaining discharge from all other sources is less than 100,000 gpd;

B. Your company is currently piloting projects as part of a research study effort with the City which will either bring the facility's total discharge to below 100,000 gpd by August 1, 1999 or use SBWR as described in number A above; or

C. Your company submits closure plans to the City indicating that the company will not be in operation after August 1, 1999. The president or Chief Executive Officer of the company must sign this closure plan. If the facility is not proceeding towards closure by March 1, 1999, the company will have to begin completing a Flow Audit Study. Partial permanent closure of production lines will be evaluated on a case-by-case basis.

4. Do I need to complete a FAS if I Completed a Mass Audit Study (MAS)?

Yes. Although there may have been projects identified in the MAS that reduced flow, the emphasis of the MAS has been copper and/or nickel reduction. The FAS is a tool to help identify water reduction and/or water reuse opportunities throughout the entire facility, not just in the manufacturing area. In the future, elements of the FAS will be included in the MAS protocol so that a Discharger will only have to complete one document instead of two separate studies. You may, however, use information from your recent MAS as appropriate.

5. Group I Dischargers: Can I have my Mass Equivalent Concentration Limit (MECL) recalculated if our facility implements flow reduction projects?

Yes. If production related flow reduction and/or water reuse projects have been identified that will result in the exceedance of the current MECL, but not in an increase in the mass that was used in calculating the existing MECL a Discharger can request that their MECL be recalculated. This will require a permit amendment and the request must be accompanied by the appropriate fee.

6. What are Cost Effective Flow Reduction Measures (CEFRMs)?

The flow reduction should occur by implementing Cost Effective Flow Reduction Measures (CEFRMs). This includes undertaking all projects and functionally interdependent groups of projects that the FAS indicates are Cost Effective and Technically Feasible.

Cost Effective

Cost Effective is defined in the municipal code as: “The total project costs, if financed over a five (5) year period at the prime interest rate published in the Wall Street Journal plus two percent (2%) at the time the project costs are being determined, do not exceed the total savings that would be generated by the project during the same five (5) year period.” Project costs shall include any financing assistance available to the Discharger, from the Environmental Enforcement Staff (EE), or any other source at a lower rate.

Technically Feasible

A flow reduction measure (or group of functionally interdependent measures) shall be deemed Technically Feasible if it has a reasonable expectation of reducing wastewater flow to the sanitary sewer, without affecting production quality or throughput.

Functionally Interdependent

Groups of projects may be interdependent in such a way that they need to be done together to be Technically Feasible or Cost Effective. Examples include:

The use of ion exchange to treat rinse water is not always cost effective. However, the use of static dragout tank(s) and counter-current rinses prior to ion exchange may make the entire system cost effective. The reduced concentration and flow may make it possible to use a smaller and less expensive ion exchange unit.

7. What are Reasonable Control Measures (RCMs)?

Reasonable Control Measures (RCMs) are defined in the Municipal Code as: "Control technologies, Best Management Practices, source control practices and waste minimization procedures which prevent or reduce the introduction of pollutants to the Sanitary Sewer System and are determined by the Director to be Cost Effective for particular industry groups, business types, or specific industrial process."

8. Is the implementation of all cost effective CEFRMs and/or RCMs identified in the FAS mandatory?

Since the Plant's average dry weather effluent flow (ADWEF) to the South Bay for 1998 is likely to be below 120 MGD, mandatory implementation of all Contingency Plan Tier I elements will not be required. However, staff was directed by the City Council to proceed with Tier I of the Contingency Plan including the FAS. Therefore, it is mandatory to complete a FAS protocol.

Implementation of projects identified in the FAS will be voluntary. Environmental Enforcement and interested stakeholders (e.g. Silicon Valley Manufacturing Group, etc.) will be working with individual companies or groups of companies, as part of various research study efforts, to expedite the implementation of projects identified through the FAS by the use of financial incentives and/or technical support. It is important to remember that although the 120 MGD flow requirement was met this year, it may not be met next year if all dischargers (industrial, commercial and residential) do not continue to minimize the amount of wastewater discharged to the Plant. If the Plant does not remain below 120 MGD ADWEF, then implementation of cost effective projects may become mandatory in the future. Our ultimate goal is to reduce the flow to the South Bay by implementing reasonable control programs. This will also allow for growth in the area.

GENERAL REQUIREMENTS

How do I Prepare the FAS?

The step-by-step preparation of the FAS is described below, and in the flow chart on page 8. There are three key parts to this effort:

1. Decide Upon a Course of Action

Review the FAS Protocol. Hold a "kick-off" meeting with the Environmental Enforcement (EE) Staff and provide an address, phone number and pager number (if appropriate) of the person who will lead your FAS team.

2. Complete the FAS

You are encouraged to contact the EE Staff during the preparation of your FAS. Bringing questions and comments up early will facilitate the review and approval process. Throughout the FAS Program, EE Staff will be available to answer questions and to interpret Protocol requirements. In addition, copies of previously completed MASs and other related documents will be made available.

The EE Staff welcomes comments and suggestions concerning how assistance could be provided to your facility throughout the process of completing the FAS, and how the process could be improved.

3. Report the Results to the EE Staff

Complete and submit all of the required worksheets to the EE Staff within 180 days of the date of the cover letter. Assemble all of your calculations and work papers into files, and hold these on-site for the EE Staff to review.

Proprietary information, as defined in the Industrial Wastewater Discharge Permit Regulations, can be kept on-site. However, a version without proprietary information will be required for the City's files. Information will have to be verified by a City Environmental Engineer or Source Control Inspector before the FAS can be considered complete.

After submission of the FAS by the facility, and approval by the Director of the Environmental Services Department (ESD) or an authorized designee, progress reports on the implementation of RCMs and CEFRM projects should be submitted quarterly after completing the FAS until all projects have been completed. (End of March, June, September, December)

How long do I have to complete the FAS?

Submittal of the FAS should allow sufficient time for review and approval by the EE Staff and implementation of approved measures. All Dischargers are encouraged to complete this process as soon as possible but no later than 180 days after notification.

What do I Submit?

The FAS report should include an evaluation of all processes that use water and/or generate wastewater at your facility. The FAS should include the following:

1. COVER SHEET

Complete the attached cover sheet in its entirety.

2. FAS WORKSHEETS

The worksheets are categorized into the following sections:

Section 1 - Organization Worksheets

Section 2 - FAS Cost Summary

Section 3 - Facility Flow Information

Section 4 - Reasonable Control Measures Worksheets

Section 5 – Water Flow Reduction Projects Evaluation

Section 6 – Flow Reduction Project Summary

Section 7 – Implementation Schedule

Section 8 - Certification

3. INFORMATION and IMPLEMENTATION CERTIFICATIONS

The purpose of these sections is to certify that the FAS has been completed by the appropriate personnel, that the obligations of the plan are understood, and that the information included in the submitted FAS is true. Both the person who prepared the plan and the Executive Officer that supervised the preparation of the FAS must sign the certification.

What Time Period do I use as a Tier I FAS Baseline?

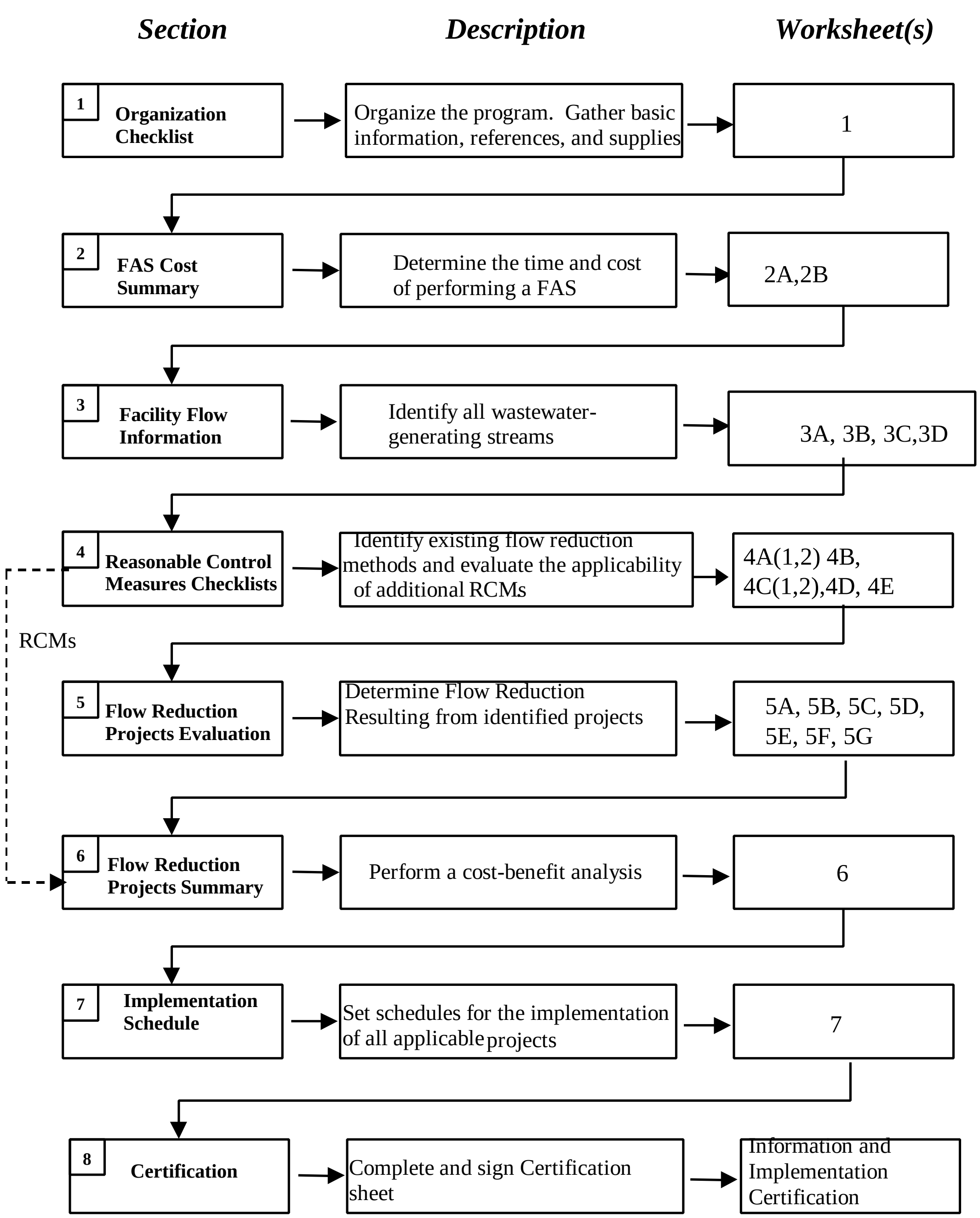
The baseline period that was used to determine Tier I is **January 1, 1997 – December 31, 1997**. The discharge data used for this determination was from the IU database and from water use data provided by water purveyors.

In February 1999, all of the 1998 flow averages will be reviewed. Any company whose discharge exceeded 100,000 gpd will become subject to the Tier 1 FAS requirements.

In the case of a New Discharger applying for a permit, a baseline should be determined from the projected flow shown in the facility's Wastewater Discharge Permit application. This will be the baseline period unless another time frame is approved by the EE Staff. These projected flows must be well documented and are subject to approval by the EE Staff.

FLOW AUDIT STUDY

Process Flow Chart



FAS COVERSHEET

Purpose

To provide general information about the facility and indicate a contact person for questions regarding the FAS.

Procedures

- Enter facility information with a brief explanation of your facility's major products, major operations, and facilities.
- Use the address where your industrial discharge point is located.
- Include your Plant Industrial Wastewater Discharge Permit number if applicable.

SECTION 1: ORGANIZATION WORKSHEETS

Purpose

To get organized for completing the FAS.

Procedures

Worksheet 1

This worksheet is a checklist of the items that can be completed and/or collected to prepare for the FAS. These items will assist you in completing the required Worksheet. Keep these items in your records and submit any that are needed in support of your FAS. Check off each task as completed.

SECTION 2: FAS COST SUMMARY

Purpose

To determine the time and cost of performing the FAS.

Procedures

Worksheet 2A

This worksheet may be used to track the amount of time that each employee spends working on the FAS. It will be used to calculate the total cost of completing the FAS. This cost can be included as a project cost during project cost evaluation. The time logs are for your use and do not need to be submitted as part of the FAS.

Worksheet 2B

This worksheet is a summary of the cost and/or time required to complete the FAS for the tasks listed. Additional activities associated with the preparation of your FAS that are not specifically listed on the worksheet may be included in the last category, "Other."

SECTION 3: FACILITY FLOW INFORMATION

Purpose

To identify processes and activities using water, and to collect, measure, and record data on the existing operations of the facility.

Sources of Information

- Existing Mass Audit Studies and Reasonable Control Measure Plans
- Existing Flow Audit Studies
- Hazardous Materials Management Plan (HMMP)
- SB-14 Source Reduction Plan
- Process Operation Records/Facility Records
- Original and As-built Construction Drawings
- Industrial Wastewater Discharge Permit Application
- Plumbing Plans

Procedures

Worksheet 3A

Prepare a site map of your facility showing the major structures including manufacturing, cooling towers, scrubbers, water treatment systems, and wastewater treatment systems.

Worksheet 3B

Prepare a detailed facility flow balance diagram (refer to example provided for Worksheet 3B). The diagram should include:

- Sources of all incoming water, and the corresponding Water Account Numbers.
- Quantities of all chemicals received and used in aqueous form greater than or equal to 1,000 gpd should be accounted for in the flow balance diagram.

- Gross flow balance of water throughout the facility. This includes irrigation, domestic (toilets, showers, cafeteria, etc.), manufacturing processes, HVAC, scrubbers, evaporation, storm drains, product, sanitary sewer, etc. Use worksheet 3C to complete the flow balance.
- The path and direction of all water usage (Example: Either to reuse in another process, treatment, directly to sample box, or the sanitary sewer, etc.).
- Specify on the diagram the number of the units that are alike. For example, represent each cooling tower as a separate block, show the number of reverse osmosis (RO) train units in parallel or sequence, etc.
- Show on the diagram the RO system, DI system, treatment systems, all flowmeters, and wastewater sampling point(s). Flowmeters should be identified as influent, influent dedicated to process, or effluent. Sample points should be identified as in the permit.

<u>Worksheet 3C</u>

List all water use practices associated with "Domestic" applications. Domestic application is defined as the individual usage of water by employees in the workplace. This includes water used in showers, bathroom usage (toilets, urinals, and sinks) and at food facilities if available on site (e.g. cafeteria).

- List the total "number of employees".
- List "the number of units available on site" for Showerheads, Toilets (identify ULFT, Low, and regular flush modes), sinks, and sanitary.
- Describe the type of unit and the estimated water flow per unit or use.
- List the "estimated usage" per day for the above applications. In the comment section, explain the method used to arrive at the estimated value. For example, based on usage per capita (employee), or usage per square foot of site, etc. Also include the used reference for this determination.
- List the "water use rate" for the cafeteria (if applicable).
- "Total" the Water usage rate for all applications. This is the total "Domestic" water influent flow rate to be used in Worksheet 3D.
- Others include swimming pool, hot tubs, floor drain primers, emergency showers and eye wash, etc.

Worksheet 3D

In order to fill out this worksheet correctly, refer to worksheet 3B as you read through the following instructions:

List all water use practices and applications throughout the facility (refer to the example provided in Worksheet 3D). Identify the processes and the equipment using the identification (ID) legend used in the Facility Block Flow Diagram (3B) and supply the following information:

- At the top left side to the worksheet, enter the following information:
    - ➢ Facility name, FAS preparer, and Industrial Wastewater Discharge Permit number (if applicable).
    - ➢ The "total influent volume to the facility." This is the total influent flow rate from all sources (potable water, well water, imported water, etc.), plus the flow rate of any liquid chemicals used in manufacturing, treatment, etc, greater than or equal to 1,000 gpd.
- Enter the "ID" and the corresponding "name" of the:
    - ➢ "Application" that uses water at the facility. This includes water used for irrigation, and domestic;
    - ➢ "Process" including manufacturing processes, and treatment; or
    - ➢ "Equipment" such as cooling towers, scrubbers, reverse osmosis, ion exchange, boilers etc.

  The ID and names listed here should match those in the facility block flow diagram (3B).
- Enter the "water source" of supply and the corresponding Water Account Number for the application, process, or equipment in the block flow diagram:
    - ➢ The water supply could be potable water supply, well water, South Bay Water Recycle (SBWR) water, or ground water reclamation.

- Reverse osmosis and ion exchange could be the source of water supply for processes using pretreated water.
- A previous process in the manufacturing flow diagram could also be the water supply source for the next process in the flow diagram.

- The "influent flow rate"
  - This is the influent flow rate for each block in the process block flow diagram (3B).
  - For domestic influent flow rate, enter the total flow rate from worksheet (3C).
  - This should be a workday average in gallons per day (gpd).
- The "effluent flow rate" is the average daily flow rate exiting the block in the block flow diagram (3B):
  - "Continue" to the next block defined on the Block flow diagram (Figure3B). List the block ID legend to which the effluent will continue to in the "To Process ID" column.

    and/or
  - is "Recycled" to a specific block or process. List the process ID legend to which this effluent will be recycled in the "To Process ID" column.
- The "wastewater flow rate" is the flow rate exiting the block and is directed to a final destination (as opposed to that which will continue/recycle to the next or other blocks in the flow diagram), as follows:
  - Flowing to the sanitary sewer,
  - Attributed to system losses (i.e. evaporation, leaks, etc.),
  - Ends up in the product, and/or
  - Shipped off-site for treatment and/or disposal.
- Enter the "Facility Sub-Total Flow Rate (current page)" for each of the Sewer, Losses, Product, and off-site columns for <u>each page</u> completed.

- Enter the "Facility Sub-Total Flow Rate (all pages)" for each of the Sewer, Losses, Product, and off-site columns for <u>all pages</u> combined.

- The sum of all wastewater leaving the facility site is the "Facility Total Flow Rate" which is the sum of the above listed four columns in the previous step.

- The "Facility Total Flow Rate" number should be equal to the "Total Influent Liquid Flow Rate" to the facility. The flow balance should be within 90% closure.

SECTION 4: REASONABLE CONTROL MEASURES WORKSHEETS

Purpose

To identify existing flow reduction projects and evaluate the applicability of additional flow related reasonable control measures (RCMs) for the industrial processes at your facility.

Procedures

This section contains worksheets for RCMs in the following categories:

- General Facility
- HVAC and Scrubbers
- Printed Circuit Board, Metal Finishing and Similar Industries
- Semiconductor Industries

Each RCM listed on the checklist is numbered and described in Appendix (A), entitled "Description of Reasonable Control Measures."

- Complete the Worksheets for the General Facility, HVAC, and Scrubbers.
- Complete worksheets that are specific to your industry only. For example, if you belong to the Semiconductor Industry, fill out worksheet 4D and mark 4C as non applicable (NA) and submit them anyways with the rest of the study.
- Review each measure and indicate if the RCM is already existing at, applicable to, or non-applicable to your facility.
- All measures have been determined to be Technically Feasible and Cost Effective. Therefore these <u>measures cannot be found to be "non-applicable" due to the cost of implementation unless a detailed cost analysis is completed according to the instructions in section 5.</u>

- If a measure listed on the checklist is determined to be "non-applicable" due to other reasons, an explanation must be included in the comment column or in attached documentation. The comment section may be used to discuss how a measure will impact processes, product quality, and waste treatment.

- RCMs determined to be applicable must be included in the Flow Reduction Projects Summary in Section 6. Include RCMs selected for implementation in Section 7.

- Include other flow reductions projects (RCMs) that have already been implemented on your site and are not listed for each sub-category.

Worksheet 4A(1&2)

General Facility: Complete one worksheet for your facility.

The use of SBWR or recycled industrial wastewater must meet all local, state, and federal regulations. ESD assistance is available to discuss and assist in regulatory and permit requirements.

Worksheet 4B

HVAC and Scrubbers: Complete an RCM worksheet for each HVAC and scrubber unit. For example, complete two separate cooling tower worksheets if you have two units existing on-site.

Worksheet 4C (1,2)

Printed Circuit Board, Metal Finishing and Similar Industries: A separate Worksheet must be completed for each industrial process wastestream in the facility.

Worksheet 4D

Semiconductor Industry: A separate Worksheet must be completed for each industrial process wastestream in the facility.

Worksheet 4E

RCM Flow Reduction Evaluation: Calculate estimated flow reductions resulting from the implementation of applicable RCMs as identified in worksheets 4A, 4B, 4C, and 4D. List the applicable RCMs and their corresponding flow rates. Applicable RCMs must also be included in the completion of sections 6 & 7.

- Enter the project "name" and "number" for each applicable RCM.
- Enter the flow rates for each project "before" the application of the RCM, "after" the application of the RCM, the flow rate "change" and "% change" resulting from implementing the RCM.
- List the method used to determine the "after" flow to the sewer. For example "based on the RCM's projected design flow balance."

SECTION 5: WATER FLOW REDUCTION PROJECTS EVALUATION

Purpose

To identify, describe, and calculate flow reduction(s) resulting from potential projects, as well as, to forecast the costs of implementing each project. To compare the annual costs of process operation before implementation to the estimated annual operating costs after project completion.

Procedures

- Explore flow reduction projects not previously mentioned in Section 4 that may be applicable to your facility.
- Complete form 5A for the facility and each process for which it is applicable.
- Complete one set of forms (5B-5F) for each project or group of interdependent projects identified.

Worksheet 5A

Potential CEFRMs: A separate worksheet must be completed for the facility and each flow generating process in your facility for which it is applicable.

When determining applicability for these measures, an economic evaluation must be performed.

- Eliminate measures that are not applicable by providing appropriate documentation. The remaining applicable measures must be evaluated.
- Complete worksheet 5C for applicable measures that you plan on implementing. Include these measures in Sections 6 and 7.

- Complete Worksheet 5B-F for the remaining applicable measures to determine the resulting flow reduction and whether they are cost effective.
- Measures found to be Cost Effective must be included in Sections 6 and 7.

Worksheet 5B

Complete the worksheet and include a description and diagram(s) of the proposed project or group of projects.

Worksheet 5C

Indicate the estimated flow reduction(s). Describe how you estimated the reduction in the amount of flow to the Sanitary Sewer System. Complete a separate worksheet for every process block, as identified in Section 3, affected by a project.

Worksheet 5D

Record the quantity and unit cost of implementing the project, including the costs detailed on the form and other costs as appropriate. Include the value of equipment, which can be salvaged for another operation or resold as a credit against the overall cost of the project.

Use the requested information to determine the total cost of the project in two ways. First assume the costs will be funded without borrowing money; and second, assume that funds will have to be borrowed at the prevailing interest rate, as defined in the Municipal Code as, “the prime interest rate published in the Wall Street Journal plus 2% at the time the project costs are being determined.”

NOTE: EE staff are aware that estimated and actual project costs can vary greatly and that these variances affect private sector decisions to proceed with future projects. EE staff will be requesting follow-up data on the actual costs of implementing flow reduction projects, so that true environmental costs and savings of flow reduction activities can be documented, assessed, and used to modify programs accordingly.

Worksheet 5E

Determine what the annual cost of operating and maintaining the process is now, prior to implementing the flow reduction project. This cost will be used as the baseline used to compare the cost impact of the project, that is, to determine net cost/savings.

Worksheet 5F

Estimate the annual cost of operating and maintaining the process in the first year following implementation of the flow reduction project.

If you anticipate that the costs will change substantially in the second through fifth years of operation following implementation, please copy Worksheet 5F, annotate the years in which the changes are expected, and fill out the form for those years.

Worksheet 5G

Compute the simple cost-offset period for each project or group of projects, by dividing the initial investment cost by the change in the annual operating costs, pre- and post-implementation. Dischargers, who expect substantial changes in their operating costs between the first year of implementation and the following four years, may want assistance in calculating this worksheet. If you want help, contact your Source Control Inspector to arrange for assistance.

SECTION 6: FLOW REDUCTION PROJECTS SUMMARY

Purpose

To summarize the cost of implementing the identified flow reduction projects and the amount of flow reduction expected. The identified flow reduction projects will include any RCMs identified in Section 4 as applicable, any potential CEFRMs from Section 5A, and any other projects you have identified in Section 5.

Procedures

<u>Worksheet 6</u>

List the proposed flow reduction projects, including applicable RCMs and CEFRMs, their associated flow reduction, cost of installation, annual cost, and payback period.

SECTION 7: IMPLEMENTATION SCHEDULE

Purpose

To schedule the implementation of all selected flow reduction projects.

Procedures

Worksheet 7

List all selected flow reduction projects by ID number and name. Provide the planned project implementation start and completion dates in the appropriate columns.

Progress reports on the implementation of RCMs and CEFRMs should be submitted quarterly after completing the FAS until all projects have been completed. (End of March, June, September, December).

SECTION 8: CERTIFICATION

Purpose

To certify that the FAS has been completed by the appropriate personnel, the obligations of the study are understood, and the information included in the submitted FAS is true.

Procedures

<u>Information and Implementation Certification</u>

- Provide the requested information.
- Make sure the person that prepared the FAS and the Executive Officer that supervised the FAS preparation both sign the certification.

WORKSHEET 8
Flow Audit Study
Information and Implementation Certification

I certify that:

1. I am knowledgeable of the processes that generate wastewater at this facility, or that I personally supervised the preparation of this FAS by someone under my authority.
2. I have the authority to obligate this facility to implement the Flow Audit Study as submitted. I certify that all selected flow reduction projects will be implemented as described on the time schedule submitted to and approved by the City of San José Environmental Services Department (ESD).
3. I will notify ESD in writing of any changes to the FAS and timeline due to planned or unforeseen circumstances or unexpected results. I understand that any changes are subject to EE Staff approval prior to implementation. I understand that any changes to the assumptions used to determine any projects must be reported as an amendment to this FAS.
4. I certify that the information in the FAS is true to the best of my knowledge.

Prepared By: ______________________________ ______________________
Phone

Signature: ______________________________ ______________________
Date

______________________________ ______________________
Name of Principal or Executive Officer Phone

______________________________ ______________________
Signature of Principal or Executive Officer Date

____
Name of Facility

____
Address of Facility

____
Address of Discharge (if different)

____
Industrial Discharge Permit Number
(If applicable)

APPENDIX A

DESCRIPTION OF REASONABLE CONTROL MEASURES

I. This description of Reasonable Control Measures (RCMs) comprises four distinct categories:

A. General Facility

B. HVAC and Scrubbers

C. Printed Circuit Board Manufacturers, Metal Finishing Industries, and Similar Businesses

D. Semiconductor Industries

Each category is described in the subsequent pages. The listed RCMs cannot be implemented on the same process line in all cases. Some RCMs are mutually exclusive; therefore, the facility must thoroughly evaluate its water usage practices. Select the specific RCMs that are most appropriate to implement. Employee safety and housekeeping issues should also be assessed as part of considering a measure.

If a measure listed on the Worksheets is determined to be "Non-Applicable," an explanation must be included in the comments column or on attached documentation. The comment section may also be used to discuss cost/benefit analysis and how a measure will impact processes, product quality, and waste treatment.

The use of these guidelines cannot be interpreted as protection against enforcement action. It is up to the Discharger to ensure compliance with all local, state, and federal regulations. Additionally, the EE Staff will not endorse or reject a project because of any specific consultant, vendor, or product line mentioned.

A. GENERAL FACILITY RCMs

General Facility RCMs are flow reduction measures that can be applied to any facility. Check with your Source Control Inspector for information on incentive programs for water conservation. The following flow reduction measures must be evaluated for each industrial process in the facility.

I. Domestic

Replace Toilets and Urinals with Ultra-low Flush Units: There are many opportunities for reducing water consumption by replacement of restroom and kitchen fixtures with low-flow units. Older, traditional toilets use 3.5 gallons per flush versus 1.6 gallons per flush of Ultra Low Flow Toilets (ULFTs). Ultra low flush urinals use only 1 gallon per flush.

Retrofit All Faucets with Aerators: Faucets can be retrofitted with aerators, flow restrictors, and other water conservation hardware to use only 2.2 gallons per minute.

Replace Shower Heads with Low Flow Units: Water-conserving showerheads should use no more than 2.5 gallons per minute. Low flow showers and faucets can also save energy by reducing hot water consumption.

II. Irrigation

Use Process Wastewater for Irrigation: Consideration should be given to using properly treated process waters or South Bay Recycled Water (SBWR) for irrigation. By utilizing process waters, a facility is doubling the value of the water purchased. By using process water, facilities can save not only on the cost of buying water for that purpose, but also on the cost of discharging the water. Process water or SBWR is a drought-proof water supply.

Use SBWR Water: SBWR is a network of pipelines, which deliver recycled water to augment a facility's water supply. SBWR is a carefully monitored and regulated water supply determined to be safe for all recycled water uses by the State of California Department of Health Services. Recycled water can be used in many places fresh water is now used including irrigation of golf courses, schools, parks, median strips, and some industrial processing and cooling. SBWR also has a nutrient value that can reduce the cost of chemical fertilizers.

The use of SBWR or recycled industrial wastewater must meet all local, state, and federal regulations. ESD assistance is available to discuss and assist in regulatory and permit requirements.

III. Pump Seals and Packing Seals

Replace with Mechanical Seal: Pump and packing water seals should be considered especially for plants with large number of pumps. First determine if seal water is necessary for the pump. Eliminate use of seal water where not necessary; e.g. convert to mechanical seals.

Replace Process Wastewater for Seal Water: Use minimum amount of seal water necessary. Convert to a closed loop seal water system for sets of pumps located close to each other. Use process waters or SBWR for seal water that cannot be reused.

IV. Liquid Ring Vacuum Pumps

Recycle Process Wastewater: In liquid ring vacuum pumps, a suitable liquid forms a liquid ring, which is retained and supported by suction, and discharge ports plates. The liquid ring forms a seal between the top tips of the rotor and the underside of the rotor boss. If the liquid ring pump uses water for priming this ring, then water generated from other uses can be used instead.

Use SBWR Water: Facilities within SBWR service area can use SBWR water for priming the pump's ring.

V. Administrative Measures

Statistical Process Control: The use of statistical process control has been applied in both the monitoring of wastewater treatment and in monitoring aqueous "plating-related" processes, although it is more common in general manufacturing. The best example of such technique is the use of process control charts (sometimes called Shewart control charts), which plot the mean and/or standard deviation of a previously determined performance variable versus time (or parts processed, or square footage) to predict trends and measure variation in the process. The desired result is a stable process that obtains maximum results with minimum materials.

Inspection/Maintenance of Facility: Inspections of the facility's production, storage, and waste treatment facilities should be conducted regularly to identify leaks and improperly functioning equipment which may lead to waste generation. These inspections should include piping systems, storage tanks, automated flow controls, and operators' techniques. It should also include floor drain primers. Frequent inspections can identify problems before they become significant. Identified problems should be fixed using appropriate corrective measures. Preventative maintenance should be incorporated into the facility's maintenance protocol. Inspections should be coordinated with the preventative maintenance schedule to reduce waste losses and improve process operating efficiency.

Employee Training: Educating employees on source reduction techniques and flow reduction concepts will allow them to develop innovative ideas specific to your facility. This may reduce water costs and minimize liability. Workers should be encouraged to offer flow reduction suggestions. A full time, ongoing commitment to flow reduction efforts must be made by owners, managers, and operators of a business. Personnel should be re-trained periodically to affirm that RCM procedures are followed and that employees know why it is beneficial to do so. Success or results of efforts should be advertised as positive reinforcement. As new developments occur in water conservation, employees should be kept informed in order for them to perform their duties more efficiently. Employee manuals should be reviewed periodically to include up-to-date information. Employee training seminars can be organized through trade associations and/or consulting firms that offer training in water conservation as part of their package of services.

B. HVAC AND SCRUBBER RCMS

I. Boilers

Use Process Wastewater for Make-Up: Using process wastewater as the makeup water for the boilers can result in significant water use and discharge reduction. Monitoring of the water quality is essential in preventing corrosion problems to boilers.

II. Cooling Towers

Maximize Cycles of Concentration to at Least 5: Cooling towers are considered among the few unit operations that can tolerate the reuse of process wastewater. Proper monitoring and automatic chemical feed control can increase the cycles of concentrations to at least 5. Many cooling towers operate between 7-8 cycles depending on the initial source of water.

Wastewater from the Semiconductor Industry is considered cleaner than potable water and is ideal for reuse in cooling towers.

Reuse RO Reject and/or Process wastewater in Cooling Towers: Reverse Osmosis reject, which is usually discharged to the sewer system, is also considered a viable option for the reuse in cooling towers. Chemical monitoring to control the hardness and alkalinity is necessary to provide protection to the interior walls of the unit from corrosion, pitting, and other problems associated with the quality of recycled water.

III. Scrubbers

Reuse Scrubber Wastewater: Facilities that have on-site scrubbers need to evaluate the reuse of scrubber water, their on-site generated process wastewater, and/or SBWR. Water quality parameters and maintenance cost are among the limiting factors in the decision making process.

Reuse Process Wastewater: Facilities that have on-site scrubbers need to evaluate the use of on-site generated process water as a make-up water for the scrubbers. The reuse of process water can be used in addition to reusing scrubber water. Water quality parameters and maintenance cost are among the limiting factors in the decision making process.

Use SBWR: Facilities that have on-site scrubbers need to evaluate the use of SBWR if the process water quality is not adequate to be used and if the facility is located within the SBWR service area.

C. PROCESS WATER REDUCTION RCMS FOR PRINTED CIRCUIT BOARD MANUFACTURERS, METAL FINISHING INDUSTRIES, AND SIMILAR BUSINESSES

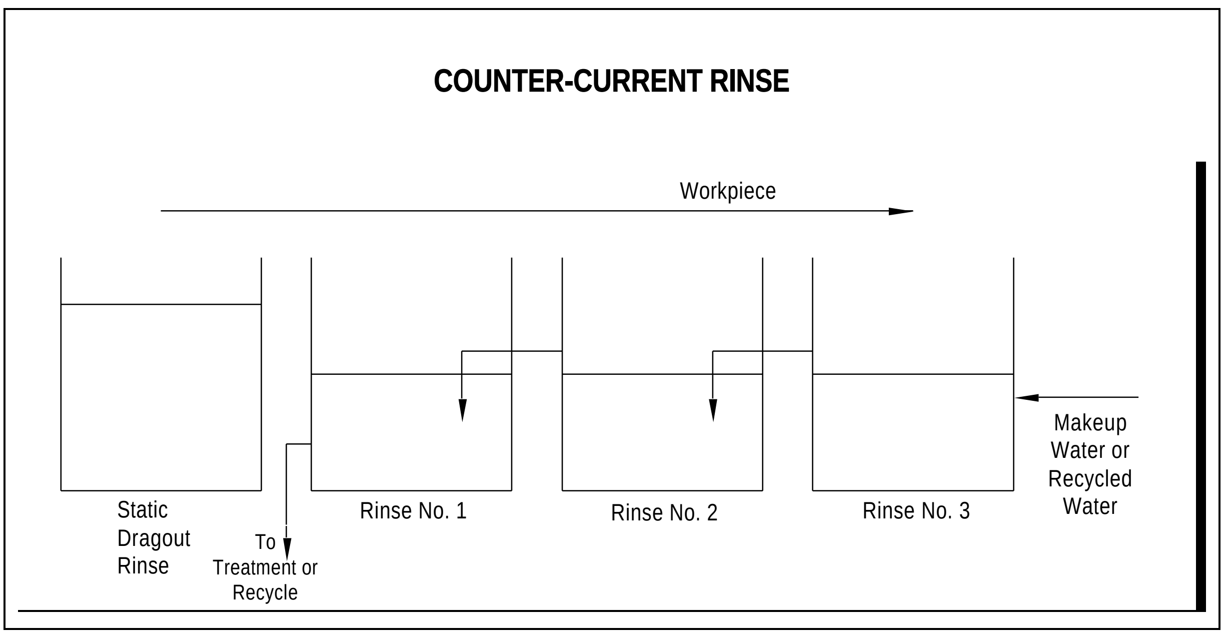
I. Rinsewater Reduction

Flow Restrictors and Manual Flow Controls: Flow restrictors limit the volume of rinse water flowing through a running rinse system. Once the optimal flowrate has been determined, these devices are used to maintain constant flow of makeup water to the system. Industries often use batch process product lines in which rinse lines are manually turned on and off throughout the day. Pressure-activated control devices such as hand, knee, or foot-pedal activated valves ensure that makeup water is not left on longer than is necessary to maintain rinse water quality after the rinse operation is completed.

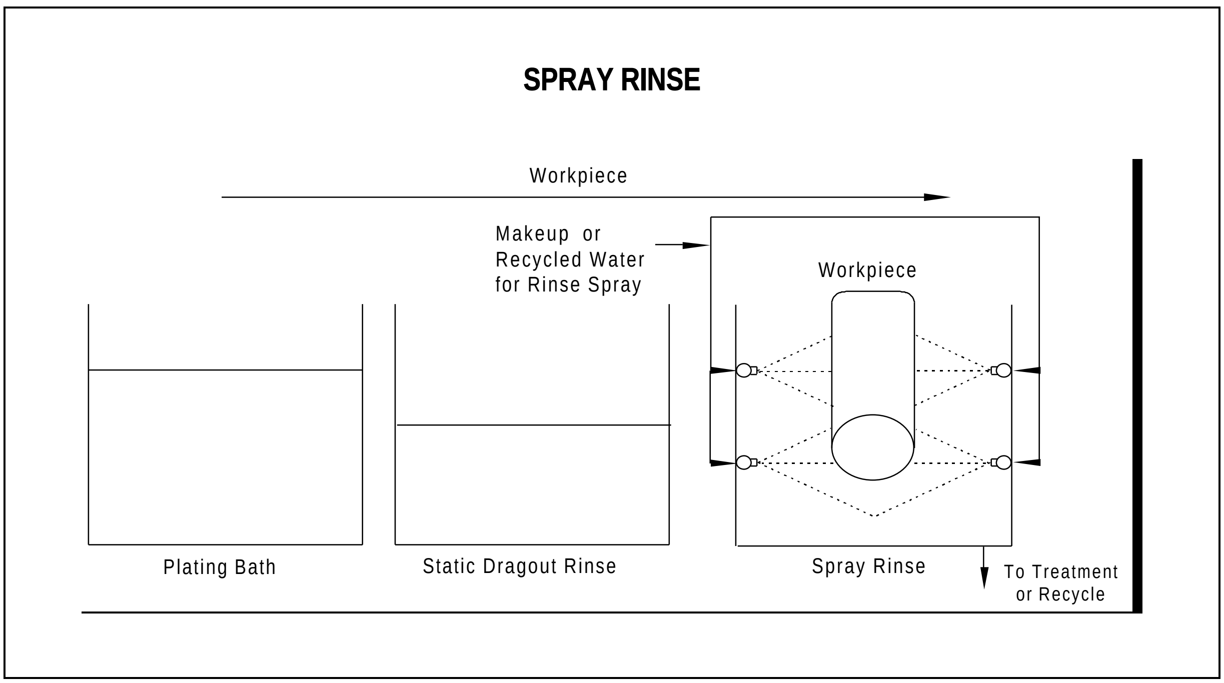
Counter-current Rinse Systems: Multiple counter-current rinse tanks are used to provide sufficient rinsing while significantly reducing the volume of rinse water used. A multi-stage counter-current rinse system uses up to 90 percent less rinse water than a conventional single-stage rinse system. Actual water savings will vary depending on the number and configuration of tanks used.

The use of a multi-stage counter-current rinse system allows (1) greater contact time between the workpiece and the rinse water; (2) greater dispersion of process chemicals into a rinse solution; and (3) more rinse water to come into contact with the workpiece. In a multi-stage counter-current rinse system, the workpiece moves in the opposite direction of the rinse water flow. The workpiece is immersed in successively cleaner rinse tanks. Counter-current rinsing should be operated with automatic or restricted water flow controls to allow minimal wastewater flow.

The disadvantage of multi-stage counter-current rinsing is that more process steps are required and additional equipment and workspace is needed. An option for a facility lacking floor space for additional tanks would be to reduce the size of the rinse tanks or to segregate existing tanks into multiple compartments (if workpiece size allows).



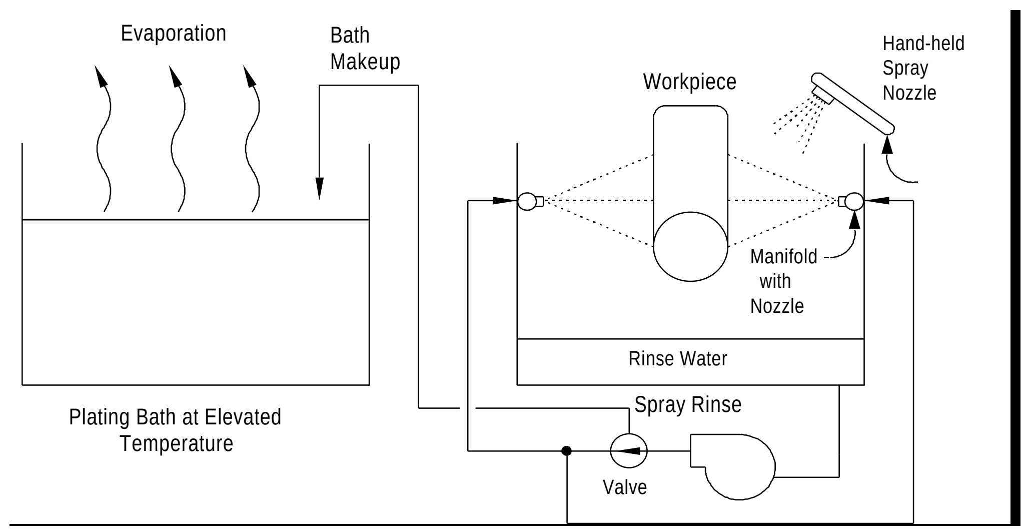
Spray Rinse Systems: Short duration spray rinsing uses between one-eighth and one-fourth the volume of water that a continuous flow rinse uses. It is highly effective for simple workpieces such as sheets. Spray rinses may not reach inner cavities of more complex workpieces. In this case, it can be combined with immersion rinsing. The application of spray rinsing as a first step in a rinse cycle is effective in reducing wastewater production. Spray rinses may be actuated manually or automatically, and may remain in operation for a short duration for workpiece rinsing.



Spray Rinse/Evaporation Makeup Systems: Use of a spray rinsing system with evaporative makeup is an effective water minimization technique that can result in zero discharge for process tanks that provide elevated temperatures and resulting evaporation losses. To maintain product quality, this system may need to be combined with processes such as ion exchange, electrowinning, electrodialysis, or an occasional bath decant to reduce accumulation of impurities.

The system uses an empty spray rinse tank. A pump feeds spray nozzles located around the inside of the tank. The workpiece is lowered into the spray zone and the drippings fall to the bottom of the tank for recirculation. A final rinse can be done with a spray nozzle using either potable water or deionized water. The used water can then be piped where needed for evaporation makeup and/or recycling. Evaporation makeup is an example of recycling that reduces waste generation.

SPRAY RINSE/EVAPORATION SYSTEM



Oversprays/Foggers: Oversprays and foggers are variations of a spray nozzle system. Oversprays use high-pressure water. Fog nozzles use high-pressure air for atomization to produce a fine mist capable of greater workpiece penetration for rinsing and lower water use than for a conventional spray nozzle. It is more often possible to use an overspray or fogger rather than a spray nozzle directly over a heated plating bath to rinse the workpiece, because less water is added to the process bath using these alternatives. Workpieces are often also able to hang longer without drying out when oversprays or foggers are used. Employee safety and housekeeping issues should be evaluated when considering this measure.

Sensor Activated Rinses: Where appropriate, a contact switch can be placed on the tank so that when racks of parts are rested in a rinse tank, the feed line water valve is opened and the rinse cycle is activated. The control circuit is set to turn off the water flow within a predetermined time period after workpieces are removed from the rinse.

Timer Flow Controls: Timers are used with spray, continuous, and sensor activated flow rinses to shut the spray off after a predetermined period and allow only the amount of water flow necessary to rinse the parts. These controls work best when the workpiece or parts to be rinsed are homogeneous from one batch of parts to the next.

Conductivity Flow Controls: A conductivity or pH meter can be used to control makeup water flow through a rinse system. A conductivity probe or pH cell is used to measure the level of dissolved solids or hydrogen ions in the rinsewater. When this level reaches a preset minimum conductivity or pH set point, the controller closes a valve that terminates the flow of water into the rinse system. When the concentration builds to the preset maximum level or pH set point, the controller opens a valve, which initiates the flow of water. Since most metal finishers have non-homogeneous production, the level of dissolved solids in the rinse solutions will likely fluctuate. Therefore, conductivity control equipment is especially valuable to the metal finishing industry. Use of these controllers can reduce product reject rates by improving water quality. Tank contents must be mixed thoroughly in order to ensure homogeneity of the water sensed by the probe, thereby resulting in effective operation of the water flow controller. Routine and frequent cleaning of probes may be necessary to ensure product quality.

II. Reuse of Rinse/Treated Water

Use in Fume Scrubber/Cooling Towers: Effluent from a final rinse operation, which is usually less contaminated than in-process rinsewaters, can be used as makeup water for fume scrubbers and cooling towers. This rinsewater may need pH adjustment prior to using it as makeup water in fume scrubbers and cooling towers. Final effluent (effluent after treatment) can be used as makeup water for the fume scrubbers and cooling towers.

Reuse of Process Rinsewater: After rinse solutions become too contaminated for their original rinse process, they may be useful for other rinse processes. Process lines and rinsewater requirements should be evaluated so rinse system arrangements can be developed to take advantage of rinsewater reuse opportunities.

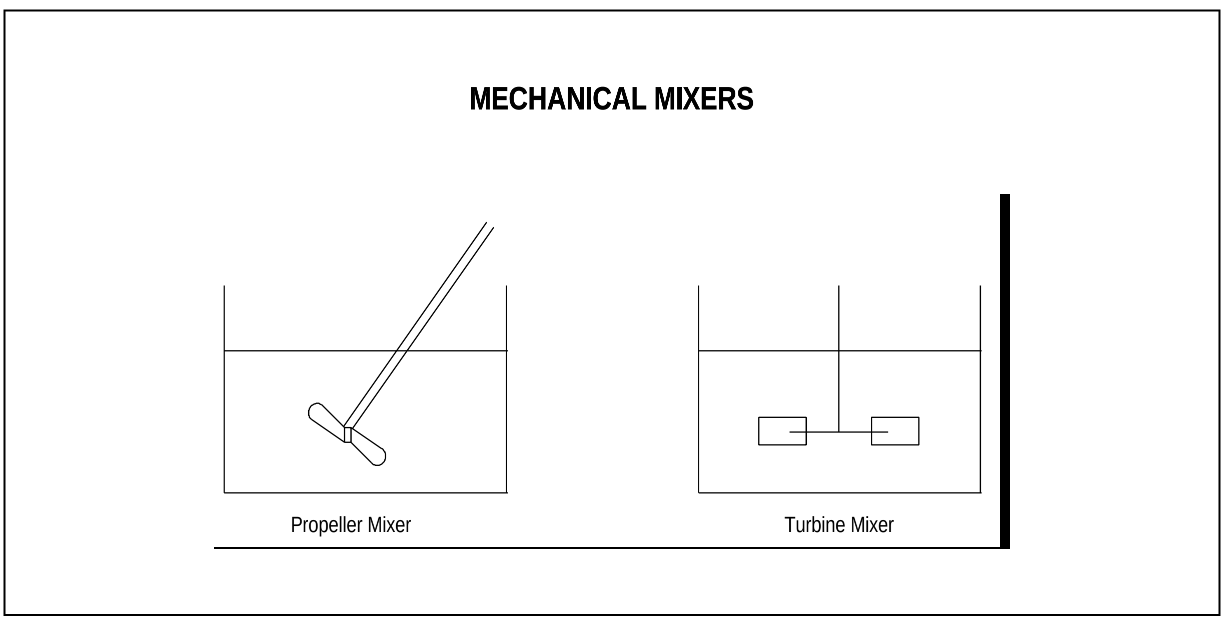
Effluent from a rinse system that follows an acid cleaning bath can be reused as influent water to a rinse system following an alkaline cleaning bath. This configuration can actually improve rinse efficiency. The neutralization reaction reduces the viscosity of the alkaline drag-out film. In some instances, unwanted precipitation of metal hydroxides onto the cleaned workpieces can occur.

Other rinsewater recycling opportunities are also available. Alkaline cleaning rinsewater effluent can be used as rinsewater for workpieces that have gone through a mild acid etch process. Effluent from a final rinse operation, which is usually less contaminated than other rinsewaters, can be used as influent for rinse operations that do not require high rinsewater quality.

Reuse of Treated Wastewater: Treated water may be reused as rinsewater for non-critical rinsing steps.

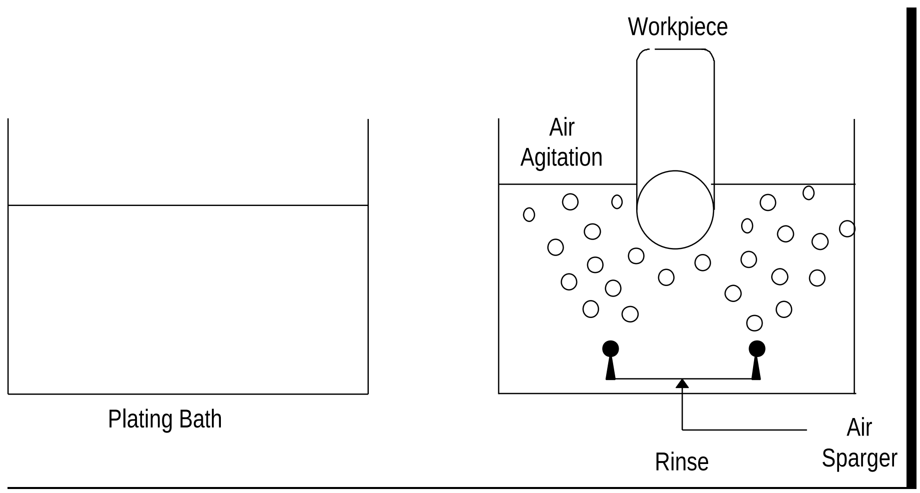
III. Rinse Agitation Measures

Mechanical Mixers: The purpose of mechanical mixing, like that of air sparging, is to maintain the contents of the tank in a completely mixed state. With mechanical mixing, turbulence is induced by means of rotating impellers, such as propellers, turbines, and paddles.



Air Agitation: The most important factor in the design of rinse systems is ensuring complete mixing of rinsewater, thus eliminating short circuiting of feed water and utilizing the entire rinse cell volume. Agitating the rinsewater by using forced air or water is the most efficient method for creating complete mixing during rinse operations. This can be achieved by pumping either air or water into the immersion rinse tank. Air agitation can provide the best rinsing because the air bubbles create improved turbulence to remove the chemical process solution from the workpiece surface. This type of agitation can be performed by pumping filtered low-pressure air into the bottom of the tank through a pipe distributor (air spargers).

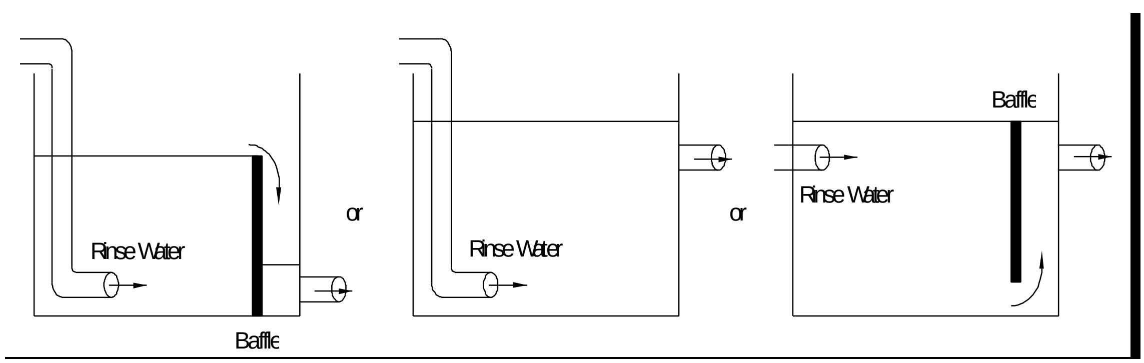
RINSE TANK AGITATION



Sonics: Rinse agitation methods, in addition to maintaining a mixed state, also provide better workpiece cleaning. Ultrasonic waves are used to create small vacuum bubbles in liquid tank contents. When these bubbles collapse, they cause a strong cleaning action on nearby parts. Ultrasonic cleaning is particularly useful for parts with hard to reach surfaces, and may allow operation at a lower temperature. Caution is advised on the use of this measure in acidic rinses.

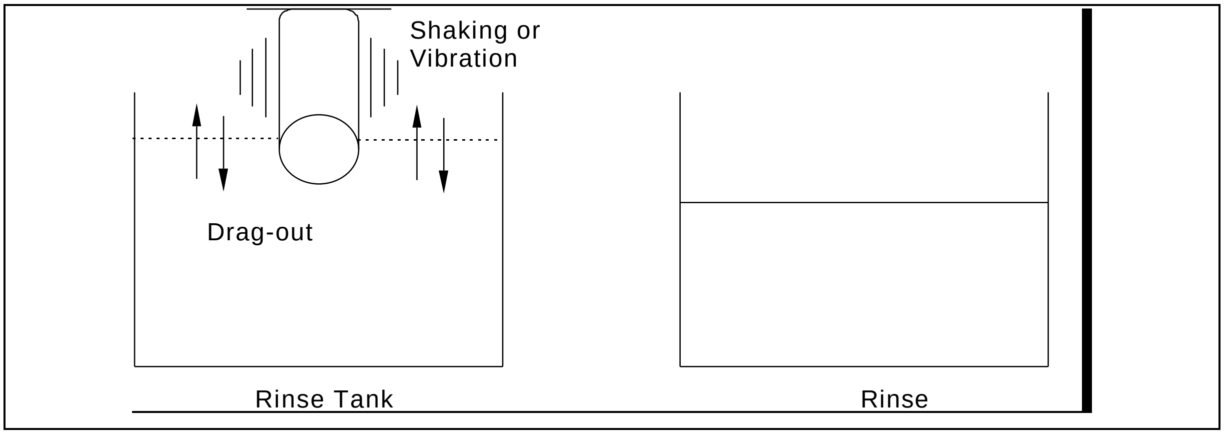
Tank Arrangement: Tank size, shape and internal configuration should be arranged such that rinsewaters circulate thoroughly and do not "short circuit" from the inlet directly to the outlet. Be sure to arrange all piping in a fashion that would eliminate a back siphon potential. Use gravity flow where possible.

TANK INLET AND OUTLET ARRANGEMENT



Workpiece Agitation: If the configuration of the workpiece permits, agitation between the workpiece and rinsewater can be performed by moving the workpiece rack in the water or creating turbulence in the feed water. Since many metal finishing plants operate hand rack lines, operators could easily move workpieces manually by agitating the hand rack. Rinsing is more effective if the pieces are raised and lowered in and out of the rinse tank rather than agitating the pieces while they are submerged. The effectiveness of this system depends on proper instruction of the operator and monitoring by the supervisor. This technique is effective for use with workpieces with large surface areas and interior surfaces that will not effectively drain.

WORKPIECE AGITATION



D. PROCESS WATER REDUCTION RCMS FOR THE SEMICONDUCTOR

I. RINSE REDUCTION

Spray Rinsing vs. Overflow and Quick Dump: Use of spray type rinsing is a more effective water reduction technique than typical overflow and quick dump types. Wet benches, for example, use an empty rinse tank with active spray bars. A pump feeds spray nozzles located on the bars around the inside of the tank. The workpiece is lowered into the spray zone and the drippings fall to the bottom of the tank for recirculation. Some tanks have built-in spray guns that perform the same function manually. The wrap around clear shield provide mutual operator safety and prevents water splashes and losses.

Using Hot Ultra-pure Water for Rinsing: Elevating the ultra-pure water temperature is effective in providing better rinsing for certain processes. This reduces the amount of water volume required.

Megasonic Rinsing: Megasonic rinsing uses high frequency acoustic waves to generate pressure waves in water. Megasonics offers selective on-line of sight cleaning, where only the side facing the transducers is cleaned, thus reducing the volume of excess rinse water. Megasonic rinsing also provides better results for surfaces that are sensitive to other sonic frequencies and their consequent cavitation effects.

Spin Rinsing: Through sequential wafer rinsing and drying steps, the spin rinsing is an alternative water rinsing technique which achieves significant reduction.

Rinse Tank Geometry: Tank size, shape and internal geometry is critical in providing optimal rinsing of the wafers. Smaller size tanks with directional flow patterns force the water in between the wafer spaces. This ensures the use of less volume of water and achieves faster and better rinsing.

Idle Flow Rate Reduction: Reducing flow rates during idle period achieves significant water reduction. Water quality monitoring sensors are required to insure optimal water rinse quality.

II Install Wet Benches with Built-in Water Recycling Units

Wet benches utilized for cleaning and rinsing in the semiconductor industry can be equipped with water recirculating units. The rinse water is usually sprayed on the work piece through spray bars, collected in a collection basin, passed through a filtration unit and reused.

APPENDIX B

POTENTIAL CEFRMs

POTENTIAL CEFRMs

This section describes several non-traditional approaches to waste treatment and recovery. Although effective in achieving flow reduction, these measures may be expensive, maintenance intensive and effective for small flows only. Unlike the previous RCMs, these measures may not be cost effective for some facilities. In determining applicability, evaluate the cost effectiveness of each measure if implemented at your site. The following pollution reduction measures must be evaluated for each copper or nickel bearing or generating process.

I. Cooling Towers

Side Stream Filtration: Side stream filtration units in cooling towers remove particles or suspended solids in the recirculating water. Sidestream filtration is applied to cooling towers where the turbidity of the supply water is high and/or airborne contaminants such as dust or oil are common.

Rapid sand filters and high efficiency cartridge filters are commonly used for such practice. Water is drawn from the center of the basin, passed through the filtration unit, and returned through spray nozzles or perforated piping. The advantages of a filtration system are reduced potential for scale and fouling and longer periods between shutdowns.

Ozonation: Ozone treatment has been claimed to greatly reduce the rate of bleed-off without the use of any additional chemicals. An allotropic form of oxygen (O_{3}), ozone reacts with mineral ions to form mineral oxides, which can be precipitated as loose sludge in the cooling tower basin or collected in a filtration system. Ozone treatment is claimed to treat corrosion and scale by oxidizing inorganic and organic compounds respectively. A typical ozonation unit consists of an air compressor, ozone generator, diffuser, or contactor, and a control system. Produced ozone is applied by an in-line contractor that mixes the ozone gas with the cooling water. The drawbacks to the use of ozone are the complexity and the capital cost of the system. Many manufacturers offer leasing arrangements. Also, ozone is toxic in large quantities, and precautions from excessive exposure are necessary.

Use South Bay Water Recycling (SBWR) water in cooling towers: Where on-site recycled water is not available or sufficient to be used in cooling towers, dischargers are encouraged to evaluate the use of SBWR water if the site is located within the service area.

Replace Cooling Towers with Mechanical Cooling: Replacing cooling towers with mechanical cooling systems can be a reasonable control measure for specific industries where the above alternatives are not available and the cost of the replacement can be offset with future water use and discharge cost reductions.

Softening: Softening treatment processes are applied to reduce water hardness, alkalinity and silica. It is considered as a pretreatment step prior to using water in cooling towers. The water is treated with lime or a combination of lime and soda ash to precipitate the ions contributing to hardness and alkalinity. Subsequent filtration is used to remove the precipitate. Softening is used to treat water with moderate to high hardness and alkalinity in the range of 150-500 ppm as $CaCO_3$.

II. Reverse Osmosis

Reverse Osmosis (RO) is a pressure-driven membrane separation process. The process uses a semi-permeable membrane that permits the passage of purified water while not allowing dissolved salts to pass through. The most common application of RO in metal finishing operations is the recovery of drag-out from nickel rinses. RO membranes are not suitable for solutions that have high oxidation potential such as chromic acid.

III. High Efficiency RO System

High efficiency reverse osmosis systems are systems that contain more than one unit arranged in various design configurations. The brine from the first stage Reverse Osmosis unit is further treated in the consequent steps resulting in producing the highest quality permeate and the least volume of waste.

IV. Ion Exchange

Ion exchange can be used to remove metals from dilute rinse solutions. The rinsewater is passed through a series of resin beds that selectively remove cations and/or anions. As the rinsewater is passed through the bed, the resin exchanges ions with the inorganic ions such as metals in the rinsewater. The metals are removed from the resin by regenerating the resin with an acid and/or alkaline solution. The metals can be removed from the regenerant solution by using electrolytic recovery techniques, or the regenerant can simply be batch treated as a spent concentrate. The treated rinsewater is of high purity and can be returned to the process bath (though filtration of salts and/or organics may be needed for reuse), or returned to the rinse system for reuse. A common use of ion exchange for process bath recovery is for the treatment of rinsewater from a chromic acid process bath.

V. Electrodeionization (EDI)

Electrodialysis employs selective membranes and an electric potential as the driving force to separate positive and negative ions in the solution into two streams. To accomplish this, the rinse solution is passed through cation and anion-permeable membranes. Cation exchange membranes allow cations such as copper or nickel to pass; while anion exchange membranes pass anions such as sulfate, chloride, or cyanide. The concentrated solutions can be recycled to the plating baths, while the ion-depleted water can be recycled through the rinse system. While electrowinning is most efficient for recovering metals from concentrated solutions such as spent plating baths, electrodialysis is very effective on dilute solutions like waste rinsewaters.

APPENDIX C

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